Dynamic Optical Properties, Underwater Visibility, and Their Relationship to Hyperspectral Remote-Sensing Reflectance

Robert A. Maffione
Hydro-Optics, Biology, and Instrumentation Laboratories
55 Penny Lane
Watsonville, CA 95076
Phone: (831) 768-0680   Fax: (831) 768-0681   Email: maffione@hobilabs.com
Award Number: N0001498C0345

LONG-TERM GOAL

My overall goal is to advance our understanding of the utility of hyperspectral and high-spatial resolution remote-sensing imagery for estimating water-column optical properties, bathymetry, and mine-hunting optical systems' performance.

OBJECTIVES

Our major objectives are to investigate two problems related to the interpretation of hyperspectral remote-sensing imagery: 1) estimating underwater visibility and associated optical parameters from remote sensing data, and 2) quantifying the effects of resuspended sediments in optically shallow waters on remote sensing data and algorithms for predicting bottom depth and water optical properties.

APPROACH

Optically shallow waters are by nature highly dynamic environments that experience a variety of processes which alter their optical properties. For the application of hyperspectral remote sensing of optically shallow waters, it is important to understand the effects some of these processes have on the optical properties of the bottom boundary layer. Waves and tides, for example, resuspend sediments in varying degrees depending on topology, sediment characteristics, and the strength of the forcing mechanism. To a hyperspectral imager, the apparent reflectance of the bottom will change dramatically depending on these bottom boundary conditions. Although the interactions of waves and tides with bottom sediments have been studied and modeled, their effects on the bottom boundary-layer optical properties and hence on the remote-sensing reflectance has rarely, if ever, been systematically studied. As pointed out by Philpot [1989] and Maritorena et al. [1994], bathymetric mapping with passive multispectral imagery is a non-unique modeling problem. That is, for example, the same RSR can result from two different bottom depths if the bottom albedos differ accordingly. Similarly, an apparent change in the bottom albedo caused by a nepheloid layer will result in errors in bottom depth estimation from the RSR. However, these errors can be anticipated, and possibly corrected, if adequate information of resuspension events in the target area can be obtained and fed into an appropriate optical model.

On the CoBOP DRI we developed a new hyperspectral radiometer system called HydroRad that is designed to measure both bottom and surface spectral irradiance (and radiance) simultaneously. From these measurements the bottom spectral irradiance reflectance and surface remote-sensing reflectance

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are obtained. Figure 1 shows a photograph of the bottom-mounted HydroRad, which includes additional HOBI Labs instruments for measuring the absorption, beam attenuation and backscattering coefficients [Dana et al., 1998]. Figure 2 shows the surface spar buoy with fiber-optic collectors for measuring downwelling irradiance and upwelling radiance from which the remote-sensing reflectance is derived. These are some of the instruments and methods we will use on HyCODE for addressing our research objectives. In addition to the time-series measurements of the bottom-boundary-layer optical properties, we will perform extensive IOP and AOP measurements of the water-column optical properties since these measurements will be needed to develop and test our shallow-water optical models. During ship deployments, we will also collect water samples for analysis of particle size distributions, dry weight and composition. These measurements will be important for understanding and modeling the optical properties and optical effects of resuspended sediments and associated optically-active matter, which is still very poorly understood.

Optical modeling will consist of four major components: 1) developing optical-property models for resuspended sediments and associated optically-active matter, 2) forward numerical modeling for solving the radiative transfer equation, 3) developing empirically-based coupled hydrodynamic-optical models for bottom-boundary layer effects, and 4) developing semi-analytical models for remote sensing of optically shallow waters that includes the optical effects of the bottom boundary layer and suspended sediments in the water column. Modeling component (1) is straightforward and simply requires the appropriate data which we will collect on this program. Component (2) is easily achieved with Hydrolight, which the author has many years of experience using. Achieving component (3) will rely heavily on the quantity and quality of the mooring data and it is recognized that these models may be regional and require statistical tuning parameters. Modeling component (4) is also likely to be regional to some degree and its general applicability will no doubt depend on how comprehensive a data set we will be able to collect on HyCODE.

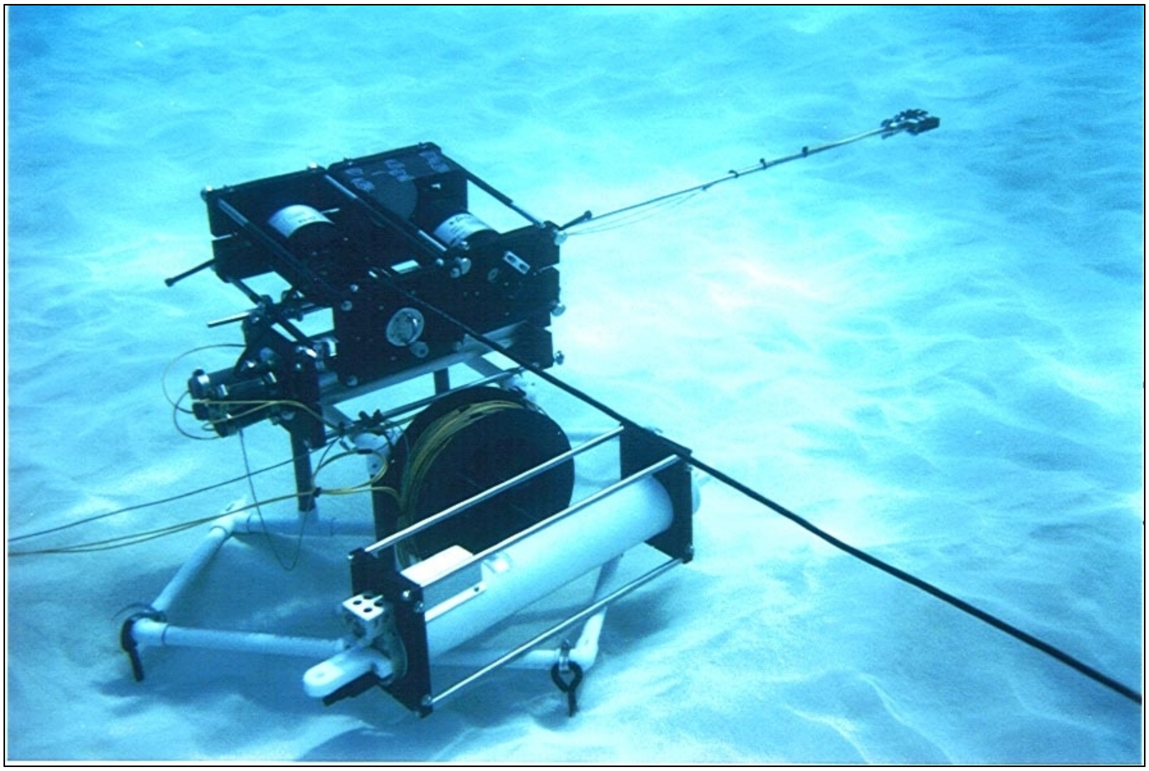

Figure 1. Photograph showing the bottom-mounted HydroRad system. The end of the rod at the upper right holds the downwelling and upwelling fiber-optic irradiance collectors. The two instruments at top are the HOBI Labs a-beta and c-beta which measure the absorption, beam attenuation, and backscattering coefficients. The HydroRad spectrometer system is located just beneath these IOP instruments. Towards the left of the photograph are the fiber-optic cables to the surface spar-buoy which contains the light collectors for measuring surface remote-sensing reflectance (see Figure 2).

Figure 2. Photograph of the fiber-optically tethered surface buoy which measures remote-sensing reflectance. The HydroRad to which this buoy is tethered is mounted on the bottom (see Figure 1), where it also measures bottom irradiance reflectance simultaneously with the remote-sensing reflectance measurement.

WORK COMPLETED

In the nine months since this project was funded, we built and deployed four HydroRad-4 hyperspectral radiometers. We also built and deployed four *a*-βeta and two *c*-βeta instruments which measure the absorption, beam attenuation, and backscattering coefficients. Deploying our instruments at mooring sites in the west Florida shelf required that our instruments operate completely autonomously for up to six months in some cases. To achieve this, we developed new underwater battery packs with the highest capacity of any packs commercially available. We also developed and successfully tested new biofouling schemes for optical sensors. Preliminary design of our new SPectral Impulse Response Sensor (SPIRS) has been completed. SPIRS will be the first profiling instrument that measures the beam spread function (BSF), and by reciprocity the point spread function (PSF). I have also made significant progress in developing algorithms for relating the BSF/PSF to IOP's and remote-sensing reflectance.

RESULTS

This project is in its first year of a five-year DRI so there are not yet significant results to be published. In the nine months since the start of this project, we have built, calibrated, and deployed numerous optical instruments. These initial test deployments were in Monterey Bay and thus far we have data covering the past six months. Shortly we will be deploying an array of optical instruments on long-term moorings in the west Florida shelf.

IMPACT/APPLICATIONS

Our long-term observations of optical properties in the west Florida shelf, continuously from moorings and synoptically from regular cruises, we further our understanding of optical variability in this type of coastal environment. This will allow us to develop and test predictive models of optical properties based on coupled circulation, productivity, and bio-optical models. Our parallel research on the relationship between underwater visibility and beam propagation parameters to remote-sensing reflectance will then allow us to estimate optical system performance based on remote-sensing imagery.

TRANSITIONS

The instruments and methods for long-term optical mooring that we have developed for this project are being used by HyCODE colleagues working at the LEO 15 site. They are also being used on a NOPP effort being conducted in the Monterey Bay area by NPS, MBARI, and others.

RELATED PROJECTS

I am working closely with investigators at USF (Carder, Weisberg, Walsh) to instrument an array of mooring sites in the west Florida shelf and collaborate on integrating the measurements into a coupled model being developed for this region.

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